

**TITLE: PREVENTING DEPOSITION OF FOULING AGENTS ONTO EQUIPMENT**

**FIELD OF INVENTION**

5           The present invention relates to methods and compositions to prevent deposition of fouling agents onto handling equipment. Specifically, the invention relates to the use of N,N-disubstituted amides, most preferably N,N-dialkylamides, in solvent recovery systems to prevent deposition of solids formed prior to or during solvent recovery in a diene plant.

10       **BACKGROUND OF INVENTION**

          A frequent problem in the chemical industry is deposition of insoluble materials onto equipment handling reactant and product streams. One area where this problem is manifested is in solvent recovery units. Fouling of reboilers and trays of distillation columns occurs due to precipitation of fouling agents. Fouling or  
15       deposition during solvent recovery causes flow and temperature control problems, both of which reduce the efficiency of the solvent recovery process and increase maintenance costs of the unit.

          Sometimes fouling can be partially ameliorated by adding a polymerization inhibitor to inhibit polymerization of unsaturated moieties, such as 1,3-butadiene or  
20       isoprene. However, polymerization inhibitors usually do not stop all of the polymerization, and therefore do not stop all of the fouling by these agents. Plus, the feed to a solvent distillation column may already contain polymer which precipitates and fouls the heat exchangers and trays of the distillation tower.

Methods of treating streams are needed which effectively prevent or resolve fouling of the equipment used to handle fouling agents.

### **SUMMARY OF THE INVENTION**

The present invention provides a method for preventing fouling of equipment  
5 handling one or more fouling agents comprising treating a blend comprising said one  
or more fouling agents with an N,N-disubstituted amide in an amount and under  
conditions effective to form a dispersion of said one or more fouling agents in said  
blend and to prevent said one or more fouling agents from depositing on said  
equipment under conditions of operation of said equipment.

### **10 DETAILED DESCRIPTION OF THE INVENTION**

The present invention provides a method to prevent or minimize fouling of  
“equipment handling one or more fouling agents.” As used herein, the phrase  
“equipment handling one or more fouling agents” is defined to mean equipment other  
than downhole equipment designed to drill for and/or remove crude oil from a  
15 geological formation. The phrase “equipment handling one or more fouling agents”  
refers to industrial equipment for processing bulk streams comprising fouling agents.  
Such equipment includes, but is not necessarily limited to, equipment for handling:  
refinery streams; petrochemical streams; streams comprising alkenes; streams  
comprising conjugated dienes; streams comprising alkynes; streams comprising di-  
20 isocyanates; streams comprising carboxylic acids; streams comprising di-carboxylic  
acids; streams comprising acid chlorides; streams comprising di-acid chlorides; and,  
streams comprising diols, among others.

The invention prevents or minimizes fouling by deposition from a “blend”  
defined as a stream comprising one or more fouling agents, for example, onto

components of "equipment handling one or more fouling agent, preferably, on components of a solvent recovery system. Such components include, but are not necessarily limited to heat exchangers, the bottom of the distillation column, reboilers, transfer lines, pumps, and any other components in which "fouling agents" are

5 handled or transported.

As used herein, the term "fouling agents" is defined as polymers, prepolymers and/or other materials which would become insoluble in and/or precipitate from a stream or "blend" and foul the equipment under the conditions of operation of the equipment, of which a preferred embodiment is a solvent recovery system. The

10 invention involves treating the stream or "blend," that is fed to equipment handling one or more fouling agents, preferably to a blend that is fed to a solvent recovery system, with an additive comprising a dispersant, preferably an N,N-disubstituted amide.

Without limiting the invention to a particular mechanism of action (unless

15 specified in a claim), the dispersant, preferably an N,N-disubstituted amide, is believed to disperse the fouling agent(s) in the "blend," thereby preventing agglomeration and deposition of fouling agents. Maintaining the solid or semi-solid fouling agents in a "dispersion" in the remainder of the blend renders the fouling agents unable to precipitate onto the solvent recovery equipment.

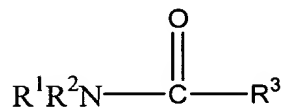
20 The blend fed to the unit comprises a solvent. The solvent may be substantially any organic solvent. Various solvents are used depending, for example, upon the type of solvent recovery unit treated and the product being made or processed. In a preferred embodiment, the solvent is an "extractive distillation solvent." As used herein, the term "extractive distillation" refers to distillation that

uses a solvent to increase the difference between (a) the volatility or boiling point of undesired components that would be inseparable by conventional distillation procedures from a substance or substances to be extracted and (b) a substance or substances to be extracted.

5           Solvents used in extractive distillation processes typically are thermally stable and non-corrosive. Extractive distillation solvents typically are polar solvents, and include, but are not necessarily limited to halogenated aromatics, alcohols, cyclic and acyclic amides, cyclic and acyclic organocarbonates, sulfones, glycols, polyglycols, phenols, amines, nitriles, and aldehydes. Specific examples of such solvents include,  
10 but are not necessarily limited to, acetonitrile, beta-methoxypropionitrile, di- and tri-chlorobenzene, benzyl alcohol, N-methylpyrrolidinone (NMP), N,N-dimethylformamide (DMF), N,N-dimethylacetamide (DMAc), propylene carbonate, 2-furaldehyde and SULFOLANE®.

          Recovery of an extractive distillation solvent preferably is by "distillation"  
15 performed after the desired product of the extractive distillation process has been recovered. It is desirable to recover the extractive distillation solvent from the remaining "blend." The "fouling agents" in the remaining blend may have a boiling point that is lower than or higher than the extractive distillation solvent. According to the present invention, the blend is distilled at temperatures that free the extractive  
20 distillation solvent from both lower and higher boiling contaminants, including, but not necessarily limited to water (by azeotropic distillation with solvent), 1,3-butadiene, 1-butene, 2-butene, butane, acetylene, methylacetylene, dimethylacetylene, allene, 1,2-butadiene and fouling agents.

The blend is treated with an N,N-disubstituted amide, which acts as a “dispersant” for fouling agents in the blend. Examples of N,N-disubstituted amides suitable for use in the invention have the following general structure:



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wherein

R<sup>1</sup> and R<sup>2</sup> independently are selected from the group consisting of hydrogen atoms; hydroxyalkyl groups having from about 1 to about 3 carbon atoms; aryl groups; aralkyl groups; alkaryl groups; branched or unbranched alkyl groups (and alkenyl groups) having from about 1 to about 30 carbon atoms, preferably from about 1 to 6 carbon atoms, most preferably from about 1 to 4 carbon atoms; cyclic groups having a total number of from about 4 to about 6 carbon atoms; and, cyclic groups wherein R<sup>1</sup> and R<sup>2</sup> are connected either directly or via a heteroatom to form a cyclic group having a total number of members of from about 5 to about 7, wherein said heteroatom is selected from the group consisting of nitrogen, oxygen, and sulfur;

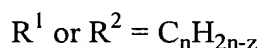
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R<sup>3</sup> is selected from the group consisting of hydrogen, aryl groups, alkaryl groups, aralkyl groups and branched or unbranched alkyl groups (or alkenyl groups) having from about 1 to 30 carbon atoms, more preferably, from about 12 to 30 carbon atoms, most preferably from about 16 to 22 carbon atoms.

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When R<sup>1</sup> and R<sup>2</sup> are connected to form a cyclic amide, and said cyclic amide comprises a nitrogen heteroatom, R<sup>1</sup> and R<sup>2</sup> each contain 2 carbon atoms and said nitrogen heteroatom comprises a substituent selected from the group consisting of hydrogen, a hydroxyalkyl group having from about 1 to about 3 carbon atoms, and an alkyl group having from about 1 to about 6 carbon atoms, preferably from about 1 to about 3 carbon atoms.

When R<sup>1</sup> and R<sup>2</sup> are branched or unbranched alkenyl, or independently are a hydrogen atom and alkenyl,



and;

when n is an even number, R<sup>1</sup> or R<sup>2</sup> comprises a quantity of carbon-carbon double bonds and said quantity increases from 1 to 2 to 3, to 4 to a maximum of n/2, with z following a first progression 1, 3, 5, 7,.... to n - 1, depending of the number of alkene groups present; and

when n is an odd number and said quantity increases from 1 to 2 to 3, to 4 to a maximum of (n-1)/2, with z following a second progression, 1, 3, 5, 7,.... to n-2.

In a preferred embodiment,

R<sup>1</sup> and R<sup>2</sup> independently are selected from the group consisting of hydrogen atoms; hydroxyalkyl groups having from about 1 to about 3 carbon atoms; branched or unbranched alkyl groups and alkenyl groups having from about 1 to about 30 carbon atoms, preferably from about 1 to 6 carbon atoms, most preferably from about 1 to 4 carbon atoms; and,

$R^3$  is selected from the group consisting of hydrogen, aryl groups, aralkyl groups, alkaryl groups and branched or unbranched alkyl groups (and alkenyl groups) having from about 1 to 30 carbon atoms, more preferably, from about 12 to 30 carbon atoms, most preferably, from about 16 to 22 carbon atoms.

Preferred embodiments of the dispersant will vary depending upon the system being treated. In a preferred embodiment for treating a butadiene solvent recovery system:

$R^1$  and  $R^2$  preferably are selected from the group consisting of hydrogen, methyl, ethyl, propyl, iso-propyl and butyl groups; and,

$R^3$  is selected from the group consisting of alkyl groups, alkenyl groups, and combinations thereof having from about 16 to about 22 carbon atoms.

In a preferred embodiment, the N,N-disubstituted amide is an amide of a fatty acid. The fatty acid residue may be a substituted or unsubstituted residue of a fatty acid which occurs in a vegetable oil. Suitable vegetable oils include, but are not necessarily limited to tall oil, palm oil, soybean oil, cottonseed oil, coconut oil, corn oil, peanut oil, canola oil, safflower oil, sunflower oil, babassu oil, castor oil, linseed oil, olive oil, and tung oil. In a preferred embodiment, the vegetable oil is selected from tall oil, palm oil, and soybean oil. Preferred fatty acids have from about 6 to about 22 carbon atoms, more preferably about 8 to about 22 carbon atoms.

A most preferred N,N-disubstituted amide used to minimize fouling in a 1,3-butadiene units is an N,N-disubstituted amide of a tall oil fatty acid, most preferably the N,N-dimethyl amide of tall oil (DMATO). The amide of the vegetable oil, as defined above, is prepared by reacting the vegetable oil with an appropriate amine.

For example, the dimethylamide of tall oil (DMATO) is prepared by reacting the tall oil fatty acids (TOFA) with dimethylamine.

Tall oil is a natural product isolated from pine trees by means of the Kraft pulping process. Components of tall oil include, but are not necessarily limited to:

- 5 rosin acids, fatty acids and unsaponifiables. Tall oil is refined by distillation. Several grades of TOFA are available depending on rosin content, unsaponifiables content, color and color stability. TOFA which have been sold in the United States, typically have the following composition (Ref. - Ullmann's Encyclopedia of Industrial Chemistry, 1985, Editors - Elvers et al., Fifth edition, Vol. A 26, pg. 67):

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Properties and Composition	Value
Acid number	197
Rosin acids,	1 %
Unsaponifiabiles,	1.5 %
Iodine value	130
Color, Gardner	3
Fatty acids, %	
Saturated	2 %
Oleic (18:1)	48 %
Linoleic (18:2)	37 %
Linolenic (18:3)	3 %
Conjugated (18:2)	6 %
Other	2.5 %

The N,N-disubstituted amide may be made in any suitable manner known to persons of ordinary skill in the art. An example is described in Furniss et al., ,

- 5 *Vogel's Textbook of Practical Organic Chemistry*, 1989, 5<sup>th</sup> Edition, pg. 708, incorporated herein by reference. Preferred N,N-dialkylamides are made as described in U.S. Patent No. 4,388,644, incorporated herein by reference.

Basically, the fatty acid and the appropriate amine are combined under elevated temperature and pressure. In the case of DMATO, for example, the TOFA  
 10 fraction (1.0 mole) is mixed with a slight molar excess (1.1 mole) of dimethylamine. In the cases of other vegetable oils (soybean, palm) in which the fatty acids are

present as triglycerides (3 fatty acids/triglyceride), 1.0 mole of the oil is mixed with 3.3 moles of the dimethylamine. These mixtures are heated slowly in a closed vessel to 170° C. at a pressure not to exceed 100 p.s.i. The reaction is held at this point for eight hours. The process has been shown to achieve at least 95 percent amidation of the constituent fatty acids. In the case of DMATO, excess amine is removed in the aqueous phase formed by the water produced in the reaction. Where triglycerides are involved, excess amine is present in the glycerol phase removed after the reaction.

Although it is not necessary for the N,N-dialkylamide to contain any solvent or additives, formulations of N,N-dialkylamides that do contain common additives such as surfactants, emulsifiers or dispersants can also be used in the methods of this invention. A preferred formulation of a N,N-dialkylamide is "DMAD," which is commercially available from Buckman Laboratories of Canada, Ltd., Vaudreuil, Quebec, Canada.

In a preferred embodiment, the dispersant comprises water and a relatively polar cosolvent that is compatible with the blend being treated and that is effective to liquefy the active component, preferably an N,N-disubstituted amide. Suitable relatively polar cosolvents include, but are not necessarily limited to acetonitrile, benzene, toluene, xylenes, heavy aromatic naphtha, kerosene, mono-butyl ether of diethylene glycol, and combinations thereof. If additives and/or solvents or cosolvents are used, the minimum amount of dispersant in the additive for a given system will depend upon the quantity of the fouling agent in the stream to be treated. A minimum amount still must be effective to form a dispersion of the fouling agents in the blend and to prevent the fouling agents from depositing on said equipment under conditions of operation of said equipment. The additive may comprise up to

100% N,N-dimethylamide of a tall oil fatty acid. A most preferred embodiment is 10% N,N-dimethyl amide, 40% butyl carbitol, and 50% water.

For ease in handling, the dispersant preferably is added in liquid form, with or without a liquifying solvent, using a metering pump. The optimum amount of  
5 dispersant for use with a particular system will be readily determined by persons of ordinary skill in the art using a simple test. An exemplary test is the following:

To a 500 mL flask equipped with distillation column, thermocouple, a spin bar and metal coupon is added 250 mL of the blend to be treated and a known dose of additive (e.g., 10 ppm of dispersant) . The coupon is adjusted so that half of the  
10 coupon is immersed into the liquid phase. The flask is then heated to reflux. Distillation ensues and distillate is collected until visible precipitation is observed. Then distillation is continued until a significant additional amount of solids are observed. The percentage of solvent or solvents distilled is recorded and the flask contents are cooled to room temperature.. The remaining liquid in the reaction flask is  
15 carefully removed and any material that adheres to the coupon, thermocouple, spin bar and the internals of the flask is dissolved in acetone/IPA. This solution is transferred to a beaker, dried, and weighed. The time required is 1.5 hours for distillation, 15 minutes for dissolving residue and 15 minutes for drying.

The test is repeated with higher dosages of additive; e.g., 20, 50, 100 and 200  
20 ppm. Each sample is distilled until the volume % distillate is the same as in the first (10 ppm of dispersant) sample tested. If the optimum (minimum) residue (fouling) occurs at a dose between, 10 and 200 ppm, the evaluation is complete. If 200 ppm of additive produces the least fouling, the test is repeated at higher doses until an optimum dose is found.

Where the solvent recovery system is a part of an extractive distillation process, wherein the solvent to be recovered is acetonitrile, the procedure would be:

To a 500 mL flask equipped with fractional distillation column, thermocouple, a spin bar and metal coupon is added 250 mL of SRC (solvent recovery column) feed and a known dose of additive (e.g., 10 ppm of dispersant) . The coupon is adjusted so that half of the coupon is immersed into the liquid phase. The flask is then heated to 213 °F. Distillation ensues and the overhead material is collected in aliquots, noting carefully the amount, temperature, pH and appearance. After the pH of the overhead samples drops to below a pH of 8, the flask contents are cooled to room temperature.

10 The remaining liquid in the reaction flask is carefully removed and any material that adheres to the coupon, thermocouple, spin bar and the internals of the flask is dissolved in acetone/IPA. This solution is transferred to a beaker, dried, and weighed. The time required is 1.5 hours for distillation, 15 minutes for dissolving residue and 15 minutes for drying.

15 The test is repeated with higher dosages of additive; e.g., 20, 50, 100 and 200 ppm. If the optimum (minimum) residue (fouling) occurs at a dose between, 10 and 200 ppm, the evaluation is complete. If 200 ppm of additive produces the least fouling, the test is repeated at higher doses until an optimum dose is found.

20 An effective amount of the dispersant is an amount effective to prevent the deposition of at least about 60% of the deposits that form in the absence of the dispersant, more preferably at least about 75%, even more preferably at least about 80%., and most preferably at least about 90 % of the deposits. Typically this will require from about 1 ppm to about 1,000 ppm of the dispersant, preferably as small an amount as possible, most preferably from about 10 to about 100 ppm. Where the

dispersant is an N,N-dimethyl amide and the blend is the feed to the solvent recovery column of a 1,3-butadiene unit, from about 20 ppm to about 50 ppm of the N,N-disubstituted amide is an effective amount.

The dispersant is added to the "blend" at any acceptable point in a given process. Where the "blend" does not include a solvent recovery tower feed, the dispersant may simply be added to the separation component or reactor used to handle the blend. Where the blend does comprise a solvent recovery tower, the dispersant preferably is added to the solvent recovery tower feed line before it enters the tower.

A solvent commonly used for extractive distillation of 1,3-butadiene is acetonitrile. The addition of the dispersant, preferably the N,N-dimethylamide of tall oil fatty acids, prevents oligomers, polymers, 1,3-butadiene and other unsaturated moieties remaining in the blend from fouling the equipment during the distillation process to recover the acetonitrile.

Where the dispersant is used to recover acetonitrile present in a blend after extractive distillation and recovery of the 1,3-butadiene product, the dispersant may be added at a variety of points. In a preferred embodiment, the dispersant is added to the feed to the solvent recovery column of a 1,3-butadiene unit. The solvent is recovered by fractional distillation to free it from both higher and lower boiling contaminants. Such contaminants include, but are not limited to, 1,3-butadiene, methylacetylene, dimethylacetylene, allene, 1,2-butadiene, oligomers and polymers.

The invention will be better understood with reference to the following example, which is illustrative only:

#### **Example I**

A test method was developed to simulate the fouling in a solvent recovery column of a 1,3-butadiene plant. The test consisted of heating a sample of SRC (Solvent Recovery Column) feed to 213°F containing an amount of antifoulant, then distilling liquid overhead until the pH of the overhead liquid dropped to 8, cooling the flask contents, decanting the liquid, dissolving the residue formed in a blend of acetone and 2-propanol, evaporating the solvents and weighing the polymeric residue. Five samples and a blank were run.

In the procedure, N,N-dimethyl amide of tall oil fatty acids DMAD was obtained from Buckman Chemical Company, Memphis, Tennessee. The performance of DMAD was compared to the performance of imidazoline, a commercially available anti-fouling product.

To a 500 mL flask equipped with fractional distillation column, thermocouple, a spin bar and metal coupon was added 250 mL of SRC feed and a known dose of dispersant. The coupon was adjusted so that half of the coupon was immersed into the liquid phase. The flask contents were then heated to 213 °F. Distillation ensued and the overhead material was collected in aliquots, noting carefully the amount, temperature, pH and appearance. After the pH of the overhead samples dropped to below a pH of 8, the test was concluded. After cooling to room temperature, the remaining liquid in the reaction flask was carefully removed and any material that was adhered to the coupon, thermocouple, the spin bar and the internals of the flask was dissolved in acetone/IPA. This solution was transferred to a beaker, dried, and weighed. The time required for each step is 1.5 hours for distillation, 15 minutes for dissolution of residue and 15 minutes for solvent evaporation.

The amount of residue that was measured included both existent polymeric products and those that were formed during the test. Products were evaluated on the ability to inhibit the deposition of polymeric materials. The results are given in the following Table (each "Sample Date" represents a different sample of SRC feed):

PRODUCT	SAMPLE DATE	ppm	% INHIBITION
BLANK		----	0
An imidazoline dispersant	10/24/00	50	90
N,N-dimethyl amide of tall oil fatty acids	10/24/00	50	100
N,N-dimethyl amide of tall oil fatty acids	11/16/00	250	100
N,N-dimethyl amide of tall oil fatty acids	11/16/00	50	100
N,N-dimethyl amide of tall oil fatty acids	12/07/00	50	100

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As can be seen from the above Table, the N,N-dimethyl amide of tall oil fatty acids completely inhibited fouling under the conditions of this test. The test demonstrates the ability of an N,N-dimethyl fatty amide to perform over a long time frame and varying conditions of the feed stream. This ability to inhibit the deposition may result from the capacity of the product to disperse the polymeric material into the stream and/or from the capacity of the product to limit the polymerization of reactants in the stream.

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The minimum dosage for purposes of the test had been determined to be around 50 ppm. The possibility of a lower dosage was not explored in this set of tests. It is important to note that no foaming was observed in this test with any of the additives and the test stream.

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Many modifications may be made to the present invention without departing from the spirit and scope of the present invention. The embodiment described herein

is meant to be illustrative only and should not be taken as limiting the invention,  
which is defined in the following claims.

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